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IBA Rooting Hormone Improves Growth and Survival of Lipote (*Syzygium polycephaloides* [C. B. Rob.] Merr.)

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Abstract

Lipote (*Syzygium polycephaloides*) is an important native tree due to its medicinal plant properties, and it offers a variety of products. However, this species is considered vulnerable and has the potential to become endangered. Studies on the vegetative propagation of *S. polycephaloides* can potentially contribute to its immediate conservation. Knowledge on its propagation can help increase the population of *S. polycephaloides*, and is useful in preserving the genetic material of desirable parent plants to increase the production of fruits in a short period of time. One hundred sixty *S. polycephaloides* cuttings were raised in an improvised plastic chamber set up at Brgy. Ramada, Maria Aurora, Philippines, to determine its growth response to varying IBA and NAA concentrations. Results of analysis revealed that there is a significant difference ($p<0.001$) in percent survival, number of developed roots, length of developed roots, length of developed shoots, and number of leaves of *S. polycephaloides* cuttings after 2 months of observation. Specifically, it shows that *S. polycephaloides* applied with 3000ppm IBA (T8) obtained the highest mean in terms of percent survival (85%), number of developed roots (44), length of developed roots (10.57 cm), and number of leaves (17). Meanwhile, the untreated cuttings (control) obtained the highest length of developed shoots (12.17 cm). This means that a 3000ppm IBA application is recommended to increase the survival and improve the growth of *S. polycephaloides* cuttings compared to NAA and lower concentrations of IBA. Additionally, *S. polycephalodes* cuttings can also be produced without the application of any rooting hormones, especially if funds are limited.

Keywords

Indole butyric acid; Naphthalene acetic acid; Cuttings; Root and shoot growth; Rooting hormone: Concentration; Vulnerable; Philippine endemic tree

Introduction

Lipote (*Syzygium polycephalodes* (C.B. Rob.) Merr. which is synonymous with *S. curranii* (C.B. Rob.) Merr. is an evergreen fruit-bearing tree belonging to the family of Myrtaceae, native to the Philippines, particularly to Bicol, Samar, Laguna, and Quezon (Cayetano *et al*., 2023). *S. polycephaloides* typically grows at low and medium altitudes and bears fruit within 4 to 5 years after planting. It reaches 15 m in height, flowers in December, and ripe fruits can be harvested in July (Mitra, 2008). Ecologically, *S. polycephaloides* trees attract various birds, small mammals, and insect pollinators, as they provide food and shelter to them, and they also help purify the air and improve soil quality (Gascon *et al*., 2023). Economically, its fruits are edible. A rich source of vitamins A, B1, B2, B3, and C, and has anti-microbial, anti-cholesterol, anti-obesity, anti-diabetic, anti-inflammatory, and anti-tumor properties (Jemi *et al*., 2010). However, the population of *S. polycephaloides* in the Philippines is considered vulnerable ("*Syzygium curranii*," 2025). It may also become endangered (Stuart, 2023). The Ecosystem Research and Development Bureau (ERDB) of the Department of Environment and Natural Resources (DENR) encourages stakeholders to conduct propagation of this species to benefit from its various uses and to enrich ecosystem landscapes (Cayetano *et al*., 2023).

S. polycephaloides can be propagated using seeds, but due to its declining population (Bautista, 2025), seed supply may be limited. Further, fruit maturity and seed readiness are difficult to determine, and their dormancy needs to be addressed in propagation (Bautista and Buhong, 2024; Buhong and Vallesteros, 2025; Polishchuk, Konovalov and Brovdi 2024). As an alternative, vegetative propagation can be undertaken. Vegetative propagation is the process of taking the desirable plant parts and reproducing new plants from cuttings or tissue (Pierik and Pierik, 1997). It is a recommended approach in preserving the superior genetic quality of the parent plant (Ukrainets and Polishchuk, 2022). In addition, vegetative propagation is considered an economically viable method used in the reproduction of many fruit trees. It enhances the ability of trees to produce fruit early, which helps meet the increasing food demand caused by urbanization (Ak, Hatipoglu and Dikmetas2021). Several factors need consideration in a vegetative propagation, such as the type of cuttings (softwood, semi-hardwood, and hardwood), and the type of hormone and concentrations (Topacoglu *et al*., 2016). Literature points out that vegetative propagation can be enhanced with the use of rooting hormones (Amri, 2012; Mukhtar, 2019). Unfortunately, some rooting hormones might not be suitable for certain cuttings of plant species.

Rooting hormone is a synthetic chemical that can be applied to stem cuttings or leaf cuttings to enhance rooting. It is available in various concentrations, brand names, and forms, such as powder, liquid, and gel. Powder and gel rooting hormones are easier to use and require less precision (Blythe and Sibley, 2003). Due to increasing cultivation challenges with cuttings, synthetic rooting hormones like ANAA, NAA, and IBA are utilized to improve rooting in difficult-to-root plant varieties. These growth regulators stimulate rooting and help cuttings develop more and better roots at a faster rate. Rooting hormones allow the cuttings to better absorb water and nutrients, produce more energy, and have greater resistance to diseases, and they increase uniformity and the number of roots (Amri, 2012). Commonly used hormones are Indole Butyric Acid (IBA), typically

containing indole-3-butyric acid, and Naphthalene Acetic Acid (NAA), both belonging to the auxin group that helps promote rooting (Mariano, 2022). However, no published works are comparing IBA and NAA on the vegetative propagation of *S. polycephaloides* using wildling cuttings. The successful stem cutting propagation of the species holds the promise of increased interest in the cultivation of the fruit tree, and its early fruiting can help sustain the production of propagules of *S. polycephaloides*. This study assumes that a particular concentration of IBA and NAA rooting hormones can improve the survival, root, and shoot growth of *S. polycephaloides* cuttings compared to the control treatment.

Materials and Methods

Location of the Study

The study was conducted in Brgy. Ramada, Maria Aurora, Aurora, Philippines (Figure 1). The experimental site is located at 15° 47' 30" N, 121° 29' 30" E coordinates, at an elevation of 31.7 m above sea level. It has a mean annual rainfall of 3,287 mm and a mean temperature of 26.7˚C. Maria Aurora is a Type II Climate under the Corona classification. The setup was placed in a poly tunnel braced with bamboo slats. An ultraviolet-resistant polyethylene plastic was used to cover the tunnel in order to maintain high humidity and protect the cuttings during heavy downpours.

Collection and Preparation of Stem Cuttings

Healthy wildlings of *S. polycephaloides* of relatively uniform sizes were collected from Zabali, Baler, Aurora (Figure 1). Cutting from wildlings was used since two prior propagation experiments on *S. polycephaloides* cuttings failed to root, presumably due to the use of cuttings from very old and very young *S. polycephaloides* plants. In this experiment, the age range of wildlings used was between 1 to 1.5 year old and their average length and diameter are 10-15 cm and 5-8 mm, respectively. In order to prevent excessive moisture loss through transpiration, the collection of cuttings was done early in the morning. Collected cuttings were also immediately soaked in a pail of water and brought to the nursery. In the nursery, cuttings were cut into appropriate sizes, and then leaves from the lower part of the cuttings were removed. The remaining two to three leaves of the upper part were trimmed in half to avoid dehydration and excessive transpiration (Hosain *et al.*, 2011). The cuttings were soaked in fungicide (Kumulus) for one hour to eliminate fungal contaminants. Then the 2 cm base part of each cutting was dipped into the NAA and IBA rooting solutions for 2 hours, except for the control, which was dipped only in distilled water.

Preparation of Rooting Hormones

Various concentrations of rooting hormones were prepared, which consisted of a control treatment, a 1000 ppm, 2000 ppm, 3000 ppm, and 4000ppm of NAA, and a 500 ppm, 1000 ppm, 2000 ppm, and 3000 ppm of IBA. Commercial rooting hormones of Ramgo Hormex with 0.3 % IBA and Philor with 0.4% NAA were used in this study. The IBA was in powder form, which was weighed on a digital weighing scale to get the desired amount for the level of concentration desired. The powder was dissolved first in some 70% alcohol to make it more soluble, then distilled water was added to get the specified

concentration for the hormone solution per treatment. The determination of the desired concentration for both IBA and NAA was based on the procedure proposed by Al-Saqri and Alderson (1996). Thereafter, the different levels of rooting hormones (NAA and IBA) and the control (distilled water) were used to soak the cuttings.

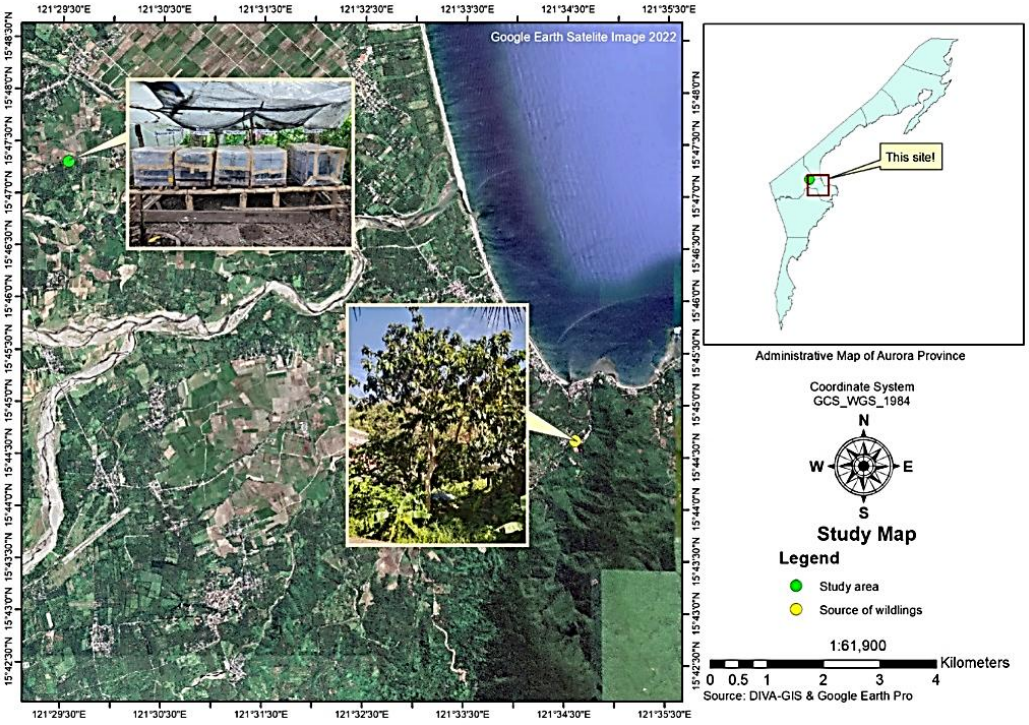

Figure 1: Location of the study site and source of wildlings cuttings

Preparation of Rooting Media and Propagation of Cuttings

The soil media used in this study is a mix of sandy soil and carbonized compost at a 1:2 ratio by volume. It had been sterilized by cooking for at least three (3) hours to eliminate fungal contaminants (Tacloy *et al*., 2022). Thereafter, the sterilized soil was placed in 4”x4” X7" black polyethylene plastic bags. A dibble was pressed into each potted soil to make a hole deep and wide enough for the sticking of a node of each cutting. Dibbling is to help avoid damage to young buds of cuttings during sticking. After sticking, petroleum jelly was applied to the upper tip of each cutting to avoid desiccation of the cuttings, which was based on the study of Castañeto and Castañeto (2015). All potted cuttings were placed inside the improvised polytunnel, having plastic divisions to separate each treatment. Watering was done once in two weeks, and the moisture inside the polytunnel was monitored daily to prevent dehydration of the propagated cuttings.

Experimental Design

The study comprised a control group and eight 8 other treatments (Table 1). Each experimental unit had 20 cuttings that were replicated four times. In each treatment, an additional four (4) samples were allotted for destructive sampling for the assessment of

rooting per treatment replication. Additional samples per treatment were added for destructive sampling since the rooting of *S. polycephaloides* cutting is difficult. Two prior experiments failed to root presumably due to the use of cutting materials from older trees and too young cutting materials from nursery-grown seedlings. Additional samples also helped ascertain the appropriate period of observing rooting and when to terminate the experiment. A total of one hundred eighty (180) cuttings with an additional thirty-six (36) sample cuttings were allotted for destructive sampling for each setup. All setups used a Complete Randomized Design (CRD) having the same layout (Table 2).

Table 1: Treatments and concentrations applied to *S. polycephaloides* cuttings

Treatment	*Rooting Hormones*	*Concentrations (ppm)*
T0	Distilled water	0
T1	NAA	1000
T2	NAA	2000
T3	NAA	3000
T4	NAA	4000
T5	IBA	500
T6	IBA	1000
T7	IBA	2000
T8	IBA	3000

Notes: Treatment 0 – Control (T0), Treatment 1 – 1000ppm NAA (T1), Treatment 2 – 2000ppm NAA (T2), Treatment 3 – 3000ppm NAA (T3), Treatment 4 – 4000ppm NAA (T4), Treatment 5 – 500ppm IBA (T5), Treatment 6 – 1000ppm IBA (T6), Treatment 7 – 2000ppm IBA (T7), and Treatment 8 – 3000ppm IBA (T8)

Table 2: Experimental layout for *S. polycephaloides* cuttings of different hormone treatments

T5	T5	T4	T2	T6	T5	T3	T3	T8
T0	T6	T7	T6	T4	T0	T1	T8	T8
T1	T2	T0	T5	T7	T4	T4	T3	T7
T0	T2	T7	T6	T3	T8	T1	T1	T2

Stem cuttings were observed for two months after planting (Santos and Galicia, 2022). The effects of treatments on the test plants were evaluated using the following parameters:

1. *Percent survival*

   In order to determine the percent survival in each treatment, the number of cuttings that developed roots was counted and recorded. Only the cuttings with developed roots and shoots were considered as surviving cuttings. The percent survival was computed using the formula:

$$\text{Percent survival} = \frac{\text{Number of surviving cuttings}}{\text{Total number of cuttings planted}} \times 100$$

2. *Number of developed roots*
The number of roots grown in each of the samples of *S. polycephaloides* stem cutting was counted manually, and the average number was taken for all subsamples per treatment replication.

3. *Length of developed roots (cm)*
Root length was determined by measuring only the longest developed root with a foot rule calibrated in centimeters from the point of origin up to the tip of the root, and the average length per treatment replication was computed.

4. *Length of developed shoots (cm)*
The length of newly grown shoots of *S. polycephaloides* stem cuttings was measured from the point of emergence up to the tip using a foot ruler calibrated in centimeters, and the average length was taken for all subsamples of each treatment replication.

5. *Number of leaves*
The newly grown leaves from the nine treatments of *S. polycephaloides* cuttings were counted, and the average leaf number was taken for all subsamples of each treatment replication.

Data Analysis

All data were analyzed using Statistical Tool for Agricultural Research (STAR) version 2.0.1. Moreover, a one-way ANOVA was employed to test the differences among the means of treatments. Duncan's Multiple Range Test (DMRT) was also employed to test the significant differences among treatments at the 0.05 level of significance (Dhital *et al*., 2025).

Results

Percent Survival of S. polycephaloides at Different Concentrations of IBA and NAA

Vegetative propagation of *S. polycephaloides* was carried out three times, where only those that used cuttings from wildlings rooted. Earlier studies revealed that cuttings from older mother trees of semi-hardwood type (first experiment), and the 6-month-old seedlings (second experiment) were difficult to root. Absence of roots and later the presence of fungal infections and molds were evident for the first two setups two months after sticking. On the other hand, successful propagation of cuttings from wildlings was observed in the third setup (Figure 2) after two months of propagation. *S. polycephaloides* cuttings applied with 3000 ppm IBA (T8) had the highest mean survival (85%) among the treatments used, this was followed by control (T0) with a mean survival of 50%. Further, cuttings applied with 500 ppm IBA (T5) had 25% survival, while cuttings applied with 1000 ppm IBA (T6) and 2000 ppm IBA (T7) obtained 20% each. Meanwhile, cuttings applied with 1000 ppm NAA (T1), 2000ppm NAA (T2), 3000 ppm NAA (T3), and 4000 ppm NAA (T4) got 0% survival (Table 3). DMRT post hoc analysis showed that T8 had a significant difference among all other treatments with *p* p-value of <.001. Also, untreated cuttings (T0) performed better survival and had a significant difference in T1, T2, T3, and T4 with a *p* value of <0.001 and in T6 and T7 with a *p* value of <.022 (Table 4).

Table 3: Results of percent survival and significant difference of *S. polycephaloides* cuttings at varying levels of NAA and IBA

Treatments	*Mean*	*SE*	*F value*	*Pr (< F)*
T0 – Control	50.00[b]	5.130	11.040***	< .001
T1 – 1000ppm NAA	.00[c]	0.0000		
T2 – 2000ppm NAA	.00[c]	0.0000		
T3 – 3000ppm NAA	.00[c]	0.0000		
T4 – 4000ppm NAA	.00[c]	0.0000		
T5 – 500ppm IBA	25[bc]	5.000		
T6 – 1000ppm IBA	20[c]	5.620		
T7 – 2000ppm IBA	20[c]	3.244		
T8 – 3000ppm IBA	85[a]	3.804		

Note: Means with the same letter superscript are not significantly different at 5% level of significance using DMRT.

Figure 2: Experimental layout of *S. polycephaloides* before the termination of the study

Table 4: Results of significant differences in the percent survival of *S. polycephaloides* with different treatments

(A) Treatment	*(B) Treatment*	*Mean Differences (A-B)*	*SE*	*Sig.*
T8	T0	-35.000***	4.897	.001
T8	T1	-85.000***	4.897	.001
T8	T2	-85.000***	4.897	.001
T8	T3	-85.000***	4.897	.001
T8	T4	-85.000***	4.897	.001
T8	T5	-60.000***	4.897	.001
T8	T6	-65.000**	4.897	.001
T8	T7	-65.000**	4.897	.001
T0	T1	50.000***	4.897	.001

(A) Treatment	*(B) Treatment*	*Mean Differences (A-B)*	*SE*	*Sig.*
T0	T2	50.000***	4.897	.001
T0	T3	50.000***	4.897	.001
T0	T4	50.000***	4.897	.001
T0	T6	30.000*	4.897	.022
T0	T7	30.000*	4.897	.022

Note: * $p < .05$, ** $p < .01$, *** $p < .001$

Number of Developed Rots of S. polycephaloides at Different Concentrations of IBA and NAA

Similarly, the number of roots was highest in T8 (3000 ppm IBA) with a mean of 44 followed by T0 (control) at 29. The average number of roots was lower for the other IBA treatments, but the lowest number of roots was most evident in those treated with NAA (Table 5). Also, cuttings applied with 4000ppm NAA (T4) did not develop any roots. It appears that the application of IBA enhanced the number of roots formed in stem cuttings of *S. polycephaloides* at higher concentrations. DMRT post hoc analysis revealed that T8 generally helped in increasing the root number of *S. polycephaloides* cuttings as compared to T2 ($p = 0.009$), T5 ($p < 0.003$), T6 ($p = 0.010$), T7 ($p = 0.002$) and T1, T3, T4 ($p < .001$) (Table 5). Also, the untreated cuttings (T0) contributed to a better increase in root number as compared to the T3 ($p = .048$) and T4 ($p = 0.025$). However, no significant difference was found for the effect of T8 and T0 in terms of root number. No significant differences were also found among T0, T1, T2, T5, T6, and T7 (Table 6).

Table 5: Average number of roots formed in *S.polycephaloides* at various levels of IBA and NAA

Treatments	*Mean*	*SE*	*F value*	*Pr (< F)*
T0 – Control	29.00^{ab}	1.329	4.693***	.001
T1 – 1000ppm NAA	6.25^{bc}	0.739		
T2 – 2000ppm NAA	12.50^{bc}	1.501		
T3 – 3000ppm NAA	1.75^{c}	0.209		
T4 – 4000ppm NAA	0.00^{c}	0.000		
T5 – 500ppm IBA	13.75^{bc}	1.095		
T6 – 1000ppm IBA	16.00^{bc}	1.452		
T7 – 2000ppm IBA	15.75^{bc}	1.274		
T8 – 3000ppm IBA	44.25^{a}	1.052		

Note: Means with the same letter superscript are not significantly different at 5% level of significance using DMRT.

Length of Developed Roots of S. polycephaloides at Various Levels of IBA and NAA

The longest length of roots was also observed in cuttings applied with 3000 ppm IBA (T8), with a mean length of 10.57 cm, followed by control (T0) at 5.60 cm, T5 (500 ppm IBA) with a mean length of 3.00 cm after two months. The rest of the roots formed were very short (Table 7). DMRT post hoc analysis again shows that T8 (3000 ppm IBA) produced the longest roots among all treatments ($p<.001$). This is followed by the control treatment (T0), which differs from T4 (4000 ppm NAA) ($p<0.001$). Lastly, T5 performed

better than T4 in improving root length (p = .001). No significant differences were found among T0, T1, T2, T3, T5, T6 and T7 (Table 8).

Table 6: Results of significant differences in the number of roots of *S. polycephaloides* with different treatments

(A) Treatment	*(B) Treatment*	*Mean Differences (A-B)*	*SE*	*Sig.*
T8	T1	-7.600***	1.538	0.001
T8	T2	-5.700**	1.538	0.009
T8	T3	-8.500***	1.538	.001
T8	T4	-8.850***	1.538	.001
T8	T5	-6.100**	1.538	0.003
T8	T6	-5.650**	1.538	0.010
T8	T7	-6.350**	1.538	0.002
T0	T3	4.850*	1.538	0.48
T0	T4	5.200*	1.538	0.025

Note: * $p < .05$, ** $p < .01$, *** $p < .001$

Table 7: Average root length (cm) of *S.polycephaloides* at various levels of IBA and NAA

Treatments	*Mean*	*SE*	*F value*	*Pr (< F)*
T0 – Control	5.60^{b}	0.155	18.235***	< .001
T1 – 1000ppm NAA	1.62^{bc}	0.249		
T2 – 2000ppm NAA	1.52^{bc}	0.365		
T3 – 3000ppm NAA	$.57^{bc}$	0.098		
T4 – 4000ppm NAA	0.00^{c}	0.000		
T5 – 500ppm IBA	3.00^{b}	0.527		
T6 – 1000ppm IBA	1.17^{bc}	0.286		
T7 – 2000ppm IBA	$.77^{bc}$	0.153		
T8 – 3000ppm IBA	10.57^{a}	0.531		

Note: Means with the same letter superscript are not significantly different at 5% level of significance using DMRT.

Table 8: Results of significant differences in the root length of *S. polycephaloides* with different treatments

(A) Treatment	*(B) Treatment*	*Mean Differences (A-B)*	*SE*	*Sig.*
T8	T0	-4.975***	0.44	.001
T8	T1	-8.950***	0.44	.001
T8	T2	-9.050***	0.44	.001
T8	T3	-10.000***	0.44	.001
T8	T4	-10.575***	0.44	.001
T8	T5	-7.575***	0.44	.001
T8	T6	-9.400***	0.44	.001
T8	T7	-9.800***	0.44	.001
T0	T4	5.600***	0.44	.001
T5	T4	-3.000***	0.44	.001

Note. * $p < .05$, ** $p < .01$, *** $p < .001$

Length of Shoots of S. polycephaloides at Various Levels of IBA and NAA

Longest shoot was observed in untreated cuttings (T0) with a mean of 12.17 cm, but it did not differ from T8 (3000ppm IBA) (p<.001). For NAA, though its application enhanced rooting, no shoots developed in cuttings applied with the various levels of NAA (Table 9). It appears that this rooting hormone is not appropriate for the species of concern. In contrast, control (T0) and cuttings applied with 3000 ppm IBA (T8) both achieved longer length of shoots compared to all other treatments. The DMRT post hoc test revealed that T0 and T8 performed better than T1, T2, T3, T4, T5, T6 and T7 (Table 8). Specifically, T5 contributed better increasing shoot length than T1, T2, T3, T4 and T6 at (p = .001). However, no significant differences were also found between T0 and T8. No significant differences were also found between T5 and T7 (Table 10).

Table 9: Average length (cm) of shoots formed in *S.polycephaloides* at various levels of IBA and NAA

Treatments	*Mean*	*SE*	*F value*	*Pr (< F)*
T0 – Control	12.17[a]	0.466	15.22***	< .001
T1 – 1000ppm NAA	0.00[c]	0.000		
T2 – 2000ppm NAA	0.00[c]	0.000		
T3 – 3000ppm NAA	0.00[c]	0.000		
T4 – 4000ppm NAA	0.00[c]	0.000		
T5 – 500ppm IBA	5.40[b]	0.878		
T6 – 1000ppm IBA	0.700[c]	0.278		
T7 – 2000ppm IBA	3.87[bc]	0.587		
T8 – 3000ppm IBA	10.00[a]	0.816		

Note: Means with the same letter superscript are not significantly different at 5% level of significance using DMRT.

Table 10: Results of significant differences in the shoot length of *S. polycephaloides* with different treatments

(A) Treatment	*(B) Treatment*	*Mean Differences (A-B)*	*SE*	*Sig.*
T0	T1	12.175	0.67	.001
T0	T2	12.175	0.67	.001
T0	T3	12.175	0.67	.001
T0	T4	12.175	0.67	.001
T0	T5	6.785	0.67	.001
T0	T6	11.475	0.67	.001
T0	T7	8.300	0.67	.001
T8	T1	-10.000	0.67	.001
T8	T2	-10.000	0.67	.001
T8	T3	-10.000	0.67	.001
T8	T4	-10.000	0.67	.001
T8	T5	4.600	0.67	.001
T8	T6	-9.300	0.67	.001
T8	T7	-6.125	0.67	.001
T5	T1	-5.400	0.67	.001

(A) Treatment	*(B) Treatment*	*Mean Differences (A-B)*	*SE*	*Sig.*
T5	T2	-5.400	0.67	.001
T5	T3	-5.400	0.67	.001
T5	T4	-5.400	0.67	.001
T5	T6	4.700	0.67	.001

Note: * $p < .05$, ** $p < .01$, *** $p < .001$

Number of Leaves of S. polycephaloides as Affected by Rooting Hormones with Different Concentrations

Table 11 shows that the highest number of leaves was observed in cuttings treated with 3000 ppm IBA (T8), with a mean of 17 after two months. Meanwhile, no leaves were developed in cuttings applied with 1000 ppm NAA (T1), 2000 ppm NAA (T2), 3000 ppm NAA (T3), and 4000 ppm NAA (T4). Moreover, table 9 shows that there were significant differences among treatments in terms of the number of leaves developed ($p<0.001$). DMRT post hoc test revealed that T8 performed better than T1, T2, T3, and T4 ($p = 0.007$). Moreover, T0 also performed better, with a larger number of leaves than T1, T2, T3, and T4 at ($p = 0.007$). However, no significant difference was found for the effect of T8, T0, T5, T6, and T7 in terms of the number of leaves. No significant differences were also found among T5, T6, T7, T1, T2, T3 and T4 (Table 12).

Table 11: Average number of leaves formed in *S. polycephaloides* at various levels of NAA and IBA

Treatments	*Mean*	*SE*	*F value*	*Pr (< F)*
T0 – Control	14.75^{ab}	0.854	4.815***	<.001
T1 – 1000ppm NAA	0.00^{c}	0.000		
T2 – 2000ppm NAA	0.00^{c}	0.000		
T3 – 3000ppm NAA	0.00^{c}	0.000		
T4 – 4000ppm NAA	0.00^{c}	0.000		
T5 – 500ppm IBA	11.00^{abc}	1.007		
T6 – 1000ppm IBA	9.75^{abc}	0.956		
T7 – 2000ppm IBA	6.25^{abc}	0.732		
T8 – 3000ppm IBA	17.00^{a}	0.723		

Note; Means with the same letter superscript are not significantly different at 5% level of significance using DMRT.

Table 12: Results of significant differences in the number of leaves of *S. polycephaloides* with different treatments

(A) Treatment	*(B) Treatment*	*Mean Differences (A-B)*	*SE*	*Sig.*
T8	T1	-3.400**	0.90	0.007
T8	T2	-3.400**	0.90	0.007
T8	T3	-3.400**	0.90	0.007
T8	T4	-3.400**	0.90	0.007
T0	T1	2.950*	0.90	0.037
T0	T2	2.950*	0.90	0.037
T0	T3	2.950*	0.90	0.037

(A) Treatment	*(B) Treatment*	*Mean Differences (A-B)*	*SE*	*Sig.*
T0	T4	2.950*	0.90	0.037

Note: * $p < .05$, ** $p < .01$, *** $p < .001$

Discussion

Percent Survival of S. polycephaloides Stem Cuttings

Based on the results of the study, cuttings from wildlings at 1 to one and a half (1.5 years old are more appropriate for vegetative propagation of *S. polycephaloides*. Older source of cuttings tends to have lower tissue differentiation, that are often present in juvenile cuttings. Very young sources, on the other hand, have lower stored food to support vegetative growth. In terms of NAA and IBA and their concentration, survival was highest in 3000 ppm IBA, which is consistent with the findings of Gilani *et al*. (2019), where higher concentrations of IBA promote better root growth. Al-Zebari and Al-Brifkany (2015) also showed that at 3000ppm IBA that cuttings of guava had the maximum number of sprouts and survival. Similarly, Sokhuma, Intorrathed and Phonpakdee (2018) obtained the highest survival (93.33%) in "Himalayan" mulberry at 3000ppm IBA. Desamero *et al*. (2022) mentioned that hardwood cuttings at times demonstrate dormancy in their metabolic activity, and the chance of survival is achieved when growth regulators are applied. According to Gilani *et al.* (2019), IBA can speed up rooting due to its ability to enhance cell division, elongation, and other metabolic activities. Further, increasing its concentration to like 3000 ppm is likely enough to enhance the activity of auxin at the cambial layer that promotes the early initiation of the root primordia. In this study, the roots of cuttings with NAA were fewer, shorter, and thinner, and developed leaves were absent, which can also be due to the short duration of the experiment. This negatively affected the survival of the cuttings in NAA treatments. Both these conditions negatively affected the survival of cuttings treated with NAA.

Number of Developed Roots of S. polycephaloides

The application of IBA enhanced the number of roots formed in stem cuttings of *S. polycephaloides* compared to the untreated and NAA of varying concentrations. It successfully produced a higher number of roots, which, as mentioned by Amina *et al*. (1995), is an advantage in enhancing anchorage once they are planted in the field. Such a result is also consistent with the results of the study of Sokhuma, Intorrathed and Phonpakdee(2018) and Desamero *et al*. (2022), who concluded that 3000ppm IBA significantly increased rooting percentage, number of roots per cutting, and root length. The reason for the better rooting of the *S. polycephaloides* might be due to maximum utilization of sugar and starch after hydrolysis, which was explained by Singh, Choudhary and Kumar (2013) in their observation of rooted cuttings of lemon. IBA was also observed by Kareem *et al*. (2016), Amri (2012), and Berleth, Scarpella and Prusinkiewicz (2007), who also reported better IBA rooting ability than NAA. Berleth, Scarpella and Prusinkiewicz (2007) explained that IBA can be changed into IAA by a mechanism parallel to fatty acid oxidation. IAA is the primary form of auxin that binds to auxin receptors and triggers signaling, which is crucial for full biological effects on the rooting of cuttings.

Length of Developed Roots of S. polycephaloides

Indole butyric acid (IBA) promoted longer roots in *S. polycephaloides* after two months. It likely enhanced root growth by stimulating cell division and elongation in the root tip, lengthening the root. Also, the more roots are developed in plants, the greater is the total root length, which is primarily due to the increase in surface area, which leads to a larger root network that enhances nutrients and water absorption. In the case of this study, both root length and number were positively influenced by 3000 ppm IBA (T8). However, this observation contrasts with the experiment conducted in *Syzygium mallaccensei*, where they observed that the higher the number of roots per cutting, the shorter the root length formed (Yusnita *et al*., 2017). Although both NAA and IBA are auxin types and are known to increase root apical dominance and lengthen roots at higher concentrations, plant response is often condition and species-specific. Here, the *S. polycephaloides* responded to IBA at higher concentration and was found to be more effective in promoting root growth, which is similar to the observation of Opuni-Frimpong *et al*. (2008) in the improved root system of *Khaya anthotheca* and *K. ivorensis,* and to Kalyoncu *et al.* (2009) and Khan (2020), who also observed the longest roots in 3000 ppm IBA concentration that was applied to *Morus alba* and *M. nigra*.

Length of Developed Shoots of S. polycephaloides

The result implies that *S. polycephaloides* cuttings can be propagated effectively using 3000 ppm IBA and control treatment, where good shooting was observed. Auxin plays a vital role in root and shoots development, where these hormones enhance the growth and development of plant tissues. There are also smaller quantities of natural auxin in terminal and axillary buds and of cuttings, which can trigger growth responses like shooting even without application of synthetic hormones (Sujata *et al*., 2022). Usually, the lower auxin concentration enhances the shooting of lateral buds, especially in the absence of terminal buds; in this case, shooting in the control treatment is likely. This result also aligns with the study of Kurepa and Smalle (2022) on low auxin. Adekola and Akpan's (2012) study on untreated stem cuttings of *J. curcas* also showed this pattern, where there is better shoot growth compared to cuttings treated with NAA and other levels of IBA. But contrasting results also occur, like in the study of Pazzini, de Melo and Ribani (2021) on the cuttings of *S. malaccense,* where the 1000 ppm NAA produced greater shoot length and better roots than the control. The longer shoots that were obtained in *S. polycephaloides* cuttings treated with 3000 ppm IBA were likely also due to the increase in cell division and cell elongation due to the actions of auxins on the shoot (Sokhuma, Intorrathed and Phonpakdee, 2018).

Number of Leaves of S. polycephaloides Developed in Varying Concentrations of NAA and IBA

More leaves were also produced by cuttings applied with 3000 ppm IBA after two months, and it is likely due to the positive effect of its activation of shooting and the more developed roots that enable access to more water and nutrients from the soil. The results aligned with the study of Gilani *et al*. (2019), who also applied IBA in *Psidium* guava cuttings and observed an increase in the number of leaves that developed. He attributed this vegetative growth to longer roots accessing more mineral nutrients and

water in cuttings with 3000 ppm IBA. This activation of shoot growth can lead to an increase in the number of active nodes that grow leaves (Dhatrikarani, 2019). Figure 3 shows the overall growth of *S. polycephaloides* at various levels of IBA and NAA, where 3000 ppm of IBA (T8) obtained the best performance compared to the other treatments after two months of observation.

Figure 3: Comparative growth and rooting of *S. polycephaloides* after two months as affected by IBA and NAA and their concentration

Conclusion

The study found that *S. polycephaloides* cuttings collected from 1 to one and a half (1.5) years old wildlings for vegetative propagation had better survival than those cuttings taken from mother trees and six-month-old seedlings. It also concluded that the best rooting hormone to apply to *S. polycephaloides* cuttings is 3000 ppm IBA, followed by the control treatment. The 3000 ppm of IBA was able to improve the survival, number of roots developed, root length, shoot length, and the number of leaves of the treated cuttings even after two months of application. This is followed by the control treatment, which developed better shoot length compared to other treatments. Rooting in NAA-treated cuttings, regardless of concentration, was impaired, where few shorter roots to none were formed, and leaves were not formed. This negatively affected the survival of

the cuttings. The NAA hormones at varying concentrations were not able to promote growth and survival in *S. polycephaloide,* which can partly be due to the specificity of NAA to particular species and conditions. Therefore, in the vegetative propagation of *S. polycephaloides,* the 3000 ppm IBA is the best hormone to apply, especially if the target is to preserve the limited plant source of *S. polycephaloides* that can fruit gregariously.

Recommendation

Based on the results of this study, it is recommended that the source of cuttings for the vegetative propagation of *S. polycephaloides* should not be too old or too young; a one (1) to one and a half (1.5) years old sapling is recommended. The 3000 ppm IBA should be applied to *S. polycephaloides* if the goal is to come up with better propagules in a short time. However, if the budget is limited, control treatment or non-application of rooting hormone can also be an option. For future research on vegetative propagation of *S. polycephaloides*, it is recommended to increase the period of observation while adopting the treatment in this study, adopt cuttings from other age cohorts, and explore other synthetic and natural rooting hormones to produce better propagules from cuttings to support the local industry in fruit production of *S. polycephaloides* for its various products.

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Authors' Declarations and Essential Ethical Compliances

Authors' Contributions (in accordance with ICMJE criteria for authorship)

Contribution	*Author 1*	*Author 2*
Conceived and designed the research or analysis	No	No
Collected the data	No	No
Contributed to data analysis & interpretation	Yes	Yes
Wrote the article/paper	Yes	No
Critical revision of the article/paper	No	Yes
Editing of the article/paper	No	Yes
Supervision	No	Yes
Project Administration	Yes	No
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